

Bone Stress Injuries Are Common in Female Military Trainees

A Preliminary Study

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Abstract Although bone stress injuries are common in male military trainees, it is not known how common they are in female trainees. It also is unclear whether asymptomatic bone stress injuries heal if intensive training is continued. We prospectively followed 10 female trainees of a military Reserve Officer Course. The subjects underwent clinical and MRI examinations of the pelvis, thighs, and lower legs at the beginning, once during, and at the end of their 3-month course. We identified two to five injuries in every female trainee, all of whom already

had the injuries at the beginning of the officer course. None of these injuries increased their severity despite vigorous training. Two-thirds were asymptomatic and low grade. Femoral and tibial shafts were the most common locations. Higher-grade injuries were more likely symptomatic, but regardless of the MRI findings, female trainees expressed only mild to moderate symptoms. Asymptomatic, low-grade bone stress injuries of the femoral and tibial shaft are common in female recruits undergoing heavy physical training. Because these injuries seem to remain constant or even disappear despite continued heavy physical activity, we do not recommend routine screening of asymptomatic trainees. As some bone stress fractures may have severe consequences (eg, in the femoral neck), symptomatic bone stress injuries should be examined and treated.

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Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained. This work was performed at Central Military Hospital.

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Introduction

A fatigue bone stress injury occurs when abnormal stress, usually in the form of multiple stress or frequent repetition of otherwise normal stress, is exerted on a bone with normal elastic resistance but unaccustomed to that action [4, 9, 12]. A typical patient history for fatigue bone stress injuries includes a rapid increase or alteration in physical loading magnitude and/or intensity of physical activity as part of a training program. Under increased physical load, bone remodeling accelerates, resulting in microfractures [8, 19]. To prevent these from coalescing into macroscopic fractures and to give them enough time to heal, adequate rest is required [13]. Because diagnosing bone stress injuries by clinical history and examination is difficult, imaging methods typically are needed to help reach an accurate

diagnosis and decide on treatment in case of a strong clinical suspicion [26].

Fatigue injuries of the lower extremities reportedly occur in athlete populations [5, 6] and among the military, especially during the beginning of the military service [22, 23]. In reports on training programs with the main focus on running, the occurrence of such injuries have ranged from 10% to 49% [6, 18], depending on the type of sport, gender, and imaging method used [2, 4, 11, 12]. Several studies have shown MRI has high sensitivity and specificity for detecting bone injuries [16, 17].

Female gender generally is considered a risk factor for bone stress injuries. In addition, the anatomic location of these injuries varies by gender [7, 15, 22]. It previously was reported MRI-diagnosed bone stress injuries of the pelvis and femoral neck are substantially more common among female recruits than among male conscripts [1, 17, 22].

The objectives of this limited prospective study were to assess the (1) occurrence, (2) prognosis, (3) anatomic distribution, (4) symptoms, and (5) association between symptoms and grades of bone stress injuries to the pelvis, femur, and tibia in female elite military trainees.

Materials and Methods

We prospectively followed all 10 female trainees of one Reserve Officer Course at the Central Military Hospital, Helsinki, Finland who entered service in 2000. Their mean age was 20.2 years (range, 19–25 years). All 10 subjects were examined by an orthopaedic surgeon at the beginning, once during, and at the end of the course. After each clinical examination, the women underwent MRI of the pelvis and the lower extremities. One trainee interrupted the course owing to health-related reasons and therefore had only the first MRI scan. The study was approved by the Medical Ethics Committee of our institution. Informed, written consent was obtained from all participants.

All Finnish men become liable for a 6-, 9-, or 12-month long military service at the age of 18 years. Military service is voluntary for women. Each year, approximately 23,000 to 26,000 male conscripts and 370 to 500 female recruits undergo training, during which identical military equipment is used by both genders. After 8 weeks of basic training, men and women, selected on the basis of physical fitness and psychological tests, are enrolled in the Reserve Officer Course. This course lasts 3 months and, in addition to military leadership education, consists of physical training, including marching, cycling, and drill, combat, or other training involving physical loading. During combat training and marching, every military trainee usually

carries approximately 26 kg (in summer) or 36 kg (in winter) of personal military equipment. At times, soldiers have to carry an additional 5 to 20 kg of team military equipment. Additionally, the trainees perform other physical exercises such as jogging, team sports, or circuit training on a weekly basis.

The histories and examinations by the orthopaedic surgeon were repeated at 6-week intervals. The history included the presence, intensity, and location of pain and the examination included palpation and estimation of the range of movement of the hip, knee, and ankle. Any other observations considered relevant for the study also were recorded. To determine the degree of pain experienced by the patient, we used a 10-point (0–10 cm) visual analog scale, where 10 = the greatest pain. Body mass index (BMI) was calculated during the beginning of the course. Three categories were used: underweight (BMI < 20 kg/m²), normal (BMI = 20–25 kg/m²), and overweight (BMI > 25 kg/m²) [20].

All subjects underwent MRI scans on a 1.0-T scanner (Signa Horizon; GE Medical Systems, Milwaukee, WI) at enrollment, at 6 weeks, and at 12 weeks. A body coil with a field of view of 32 to 48 cm × 24 to 48 cm was used to screen the pelvis and both lower extremities with a coronal STIR (short tau inversion recovery) sequence (repetition time/echo time/inversion time = 5400/17/140 ms, with two signals averaged). For the pelvis, femur, and tibia, a 256 × 224 matrix was used with a slice thickness of 4.0 or 5.0 mm with a 0.5- or 1.0-mm intersection gap. Additional sequences were taken when needed to control images. No contrast media were used. We diagnosed a bone stress injury if there were edema of the bone marrow, periosteum, and muscle surrounding the bones; fracture line; and callus in the cortical bone [14, 15]. On the STIR images, edema appeared as a high signal intensity, fracture line as a low signal intensity line, and callus as an intermediate signal intensity mass associated with the cortex.

Two radiologists (MHN, MJK) separately evaluated the MRI scans. In cases of differing interpretations, the final decision was made by consensus. On the basis of MRI findings, bone stress injuries were classified according to injury location and type into low grade (Grades I–III) and high grade (Grades IV–V) as follows: Grade I, endosteal marrow edema; Grade II, periosteal edema and endosteal marrow edema; Grade III, muscle edema, periosteal edema, and endosteal marrow edema; Grade IV, fracture line; and Grade V, callus in cortical bone [15, 16]. Although, to our knowledge, the grading system has not been validated, it has been reported in the literature [10, 16, 28]. For calculating the interobserver variability, the original separately made evaluation of the two radiologists was used. The interobserver variability in our MRI scans was 0.97, which can be considered almost perfect.

Results

The first MRI scan performed at the beginning of the officer course revealed all 10 trainees had two to five bone stress injuries on the basis of basic military training (altogether 30 injuries). The second scan after 6 weeks' service in the officer course revealed one new bone stress injury of the femoral neck (Grade IV). In addition, five injuries, which had been visible on the MRI at the beginning of the officer course, had disappeared despite the vigorous military training. For the period between 6 and 12 weeks in the officer course, 16 new injuries were detected (Table 1). None of the stress injuries seen at 6 weeks on MRI disappeared, but their severity grading did not increase either. Thus the female trainees had 30 injuries at the beginning of the officer course and 15 more developed during the course. None of the injuries increased in severity grading after the MRI scans (Figs. 1–3).

Of all 46 bone stress injuries, five were high grade (Grades IV–V), and they did not progress despite continued training (Table 1). Every female trainee had bilateral femoral bone stress injuries at some point during our followup. In addition, two trainees did not have injuries at the tibial diaphyses; these two had only unilateral injuries.

The most common anatomic locations of bone stress injuries were the femoral diaphyses followed by the tibial diaphyses (Table 2). More uncommon anatomic locations were one ramus, one tibial condyle, one femoral neck, one fibular diaphysis, and one sacral injury.

From the 30 bone stress injuries seen at the beginning of the study, 16 were symptomatic (53%). The only new injury detected between 0 and 6 weeks was symptomatic, whereas 12 injuries that caused symptoms at the beginning became asymptomatic despite vigorous training. Of the 16 new injuries detected between 6 and 12 weeks, four caused symptoms.

The symptoms increased with the grade of the injury so that all Grade III to Grade V injuries were symptomatic at some point during the study (Table 2). Subjects described the intensity of pain on a visual analog scale (1–10 points) as ranging from 1 to 4 points. The typical symptoms for femoral shaft bone stress injuries were hip, groin, and knee pain. Knee pain also was associated with bone stress injury of the tibial condyle and tibial shaft. Slight hip pain was associated with a femoral neck injury in one trainee, groin pain with an injury to the pelvic ramus in one, and gluteal pain with a sacral injury in one. Anterior tibial pain was a typical symptom for an injury in the tibial shaft. In addition to pain related to injury, five trainees reported mild or moderate pain in the lower or upper back, shoulder, and/or head and neck (Table 1).

Discussion

Bone stress injuries are common in athlete and military populations, in which subjects are exposed to a sudden increase in physical training [8, 29]. The objectives of our study were to assess the (1) occurrence, (2) prognosis, (3) anatomic distribution, (4) symptoms, and (5) association between symptoms and grades of bone stress injuries to the pelvis, femur, and tibia in female elite military trainees.

The study had obvious limitations. The sample size was small and the followup relatively short. However, our followup covered the most vigorous training period of the entire military service.

The principal finding of our study was the repeated MRI examinations conducted on physically active female military recruits revealed numerous bone stress injuries in every subject, the majority being asymptomatic and low grade. This is in accordance with a previous study [14]. One critical dilemma is whether asymptomatic bone stress injuries identified with MRI should be monitored or treated [4, 14, 20]. Also, all female military trainees already had injuries at the beginning of the officer course, most probably the result of the 8-week basic military training. Military service is voluntary for women in Finland, and therefore we may assume the female recruits are highly motivated to attend the required training and express fewer symptoms. The multitude of asymptomatic bone stress injuries seen in this study population is the result of the increased physical loading during intensive military training. We might ask whether low-grade asymptomatic bone stress injury seen on MRI represents the bone's normal response to rapidly increased physical training. However, because some bone stress fractures may have severe consequences (eg, in the femoral neck), symptomatic injuries should be examined and treated. Routine screening of asymptomatic subjects may lead only to unnecessary rest or unsubstantiated modification of the training program.

The prognoses of bone stress injuries seen on MRI scans were good: none of the injuries progressed despite the fact that physical training was continued within pain limits. A substantial proportion of the low-grade injuries disappeared despite intensive training being continued, indicating rest is not necessary for the healing process. The exception was obviously the injury in the femoral neck, which was treated according to the Finnish Defence Forces' policy with complete rest. The femoral neck is considered a high-risk area because of the potential for displacement [24, 25]. A displaced femoral neck stress fracture in a young person may have disastrous consequences because the postoperative clinical course may be complicated by osteonecrosis of the femoral head [24]. When a typical patient history includes the important signs of female gender and hip and groin pain combined with a rapid increase in physical

Table 1. Symptomatic and asymptomatic findings in the three MRI scans

Trainee	Age (years)	Weight (kg)	Height (m)	BMI (kg/m ²)	First examination			Second examination			Third examination		
					Symptoms/VAS	MRI/Grade	BSI (S)	Symptoms/VAS	MRI/Grade	BSI (S)	Symptoms/VAS	MRI/Grade	BSI (S)
1	21	56	166	20.32	Low back pain/1	Both femoral diaphyses/I	2 (0)	Left hip pain/2	Both femoral diaphyses/I	2 (1)			
2	19	65	166	23.59	Right knee pain/1	Right tibial condyle/IV	1 (1)	Left tibial pain/2	Right tibial condyle/IV	1 (0)	Right tibial and right heel pain/4, left tibial pain/2	Both femoral diaphyses/I	2 (0)
					Right knee pain/1	Both femoral diaphyses/I	2 (1)				Left tibial pain/1	Right tibial condyle/IV	1 (0)
3	19	60	170	20.76	Bilateral hip pain/2–3	Both femoral diaphyses/I	2 (2)	Left hip pain/2	Left femoral collum/I	1 (1)	Left hip pain/1	Left femoral collum/IV	1 (1)
					Low back pain/1								
4	20	57	166	20.69	Bilateral knee pain/2–3	Both femoral diaphyses/I	2 (2)				Left hip pain/1	Both femoral diaphyses/I	2 (1)
					Bilateral knee pain/2–3	Both tibial diaphyses/II	2 (2)					Right tibial diaphyses/I	1 (0)
					Right knee pain/2	Right fibular diaphyses/I	1 (1)					Right distal tibial diaphyses/I	1 (0)
					Shoulders/1	Both femoral diaphyses/I	2 (0)					Both femoral diaphyses/I	2 (0)
5	20	63	167	22.59				Head–neck pain/1	Both femoral diaphyses/I	2 (0)	Head–neck pain/2, shoulders/2, upper back/2	Both femoral diaphyses/I	2 (0)
6	25	54	157	21.91	Left knee pain/1	Both femoral diaphyses/I	2 (1)						
					Shoulders/2–3			Head–neck pain/2 Shoulders/1	Both femoral diaphyses/I	2 (0)	Right foot pain/2 Shoulders/2	Both femoral diaphyses/I	2 (0)
												Right tibial diaphyses/I	1 (0)

Table 1. continued

Trainee	Age (years)	Weight (kg)	Height (m)	BMI (kg/m ²)	First examination			Second examination			Third examination		
					Symptoms/VAS	MRI/Grade	BSI (S)	Symptoms/VAS	MRI/Grade	BSI (S)	Symptoms/VAS	MRI/Grade	BSI (S)
7	19	67	165	24.61	Right tibial pain/4	Both tibial diaphyses/V, II	2 (1)	Right tibial pain/3 Low-back pain/1 Shoulders/2	Both tibial diaphyses/I	2 (1)	Upper-back pain/2, shoulders/2, head-neck pain/2	Both tibial diaphyses/I	2 (0)
8	19	57	164	21.19	Bilateral tibial pain/1	Both femoral diaphyses/I Both tibial diaphyses/I Both femoral diaphyses/I Both femoral diaphyses/I	2 (0) 2 (2) 2 (0) 2 (0)	Right heel pain/1	Both femoral diaphyses/I Both tibial diaphyses/I Both femoral diaphyses/I Both femoral diaphyses/I	2 (0) 2 (0) 2 (0) 2 (0)	Right heel pain/1	Both femoral diaphyses/I Both tibial diaphyses/I Both femoral diaphyses/I Both femoral diaphyses/I	2 (0) 2 (0) 2 (0) 2 (0)
9	19	61	172	20.62		Both femoral diaphyses/I	2 (0)						
10*	28	54	159	21.36	Left groin pain/1	Both femoral diaphyses/I	2 (1)						
					Upper back pain/1	Left upper ramus/V	1 (1)						
					Upper back pain/1	Left lower ramus/III	1 (1)						
Mean	20.9	59.4	165	21.76			Total 30 (16)			Total 22 (3)			Total 38 (5)

* This trainee interrupted the course owing to health-related reasons, and therefore, only had the first MRI scan; BMI = body mass index; VAS = visual analog scale (0–10); BSI = bone stress injury; S = symptoms.

Fig. 1A–B A 19-year-old female trainee experienced slight, right-sided gluteal pain during the third month of the 3-month course. (A) A coronal STIR image reveals endosteal edema in the proximal femoral shaft, which appeared on the first, second, and third MR images (arrows). (B) A tiny fracture line on the right side of the sacrum with surrounding edema is visible on the third MR image (arrow).

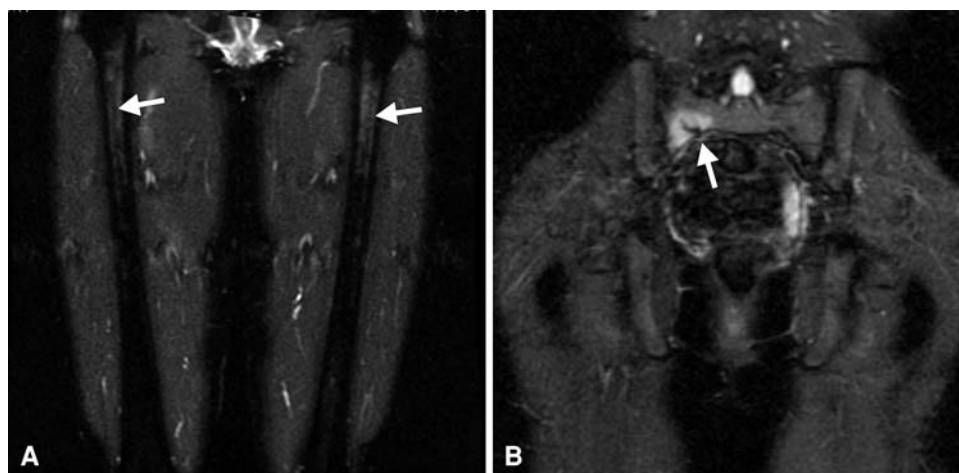
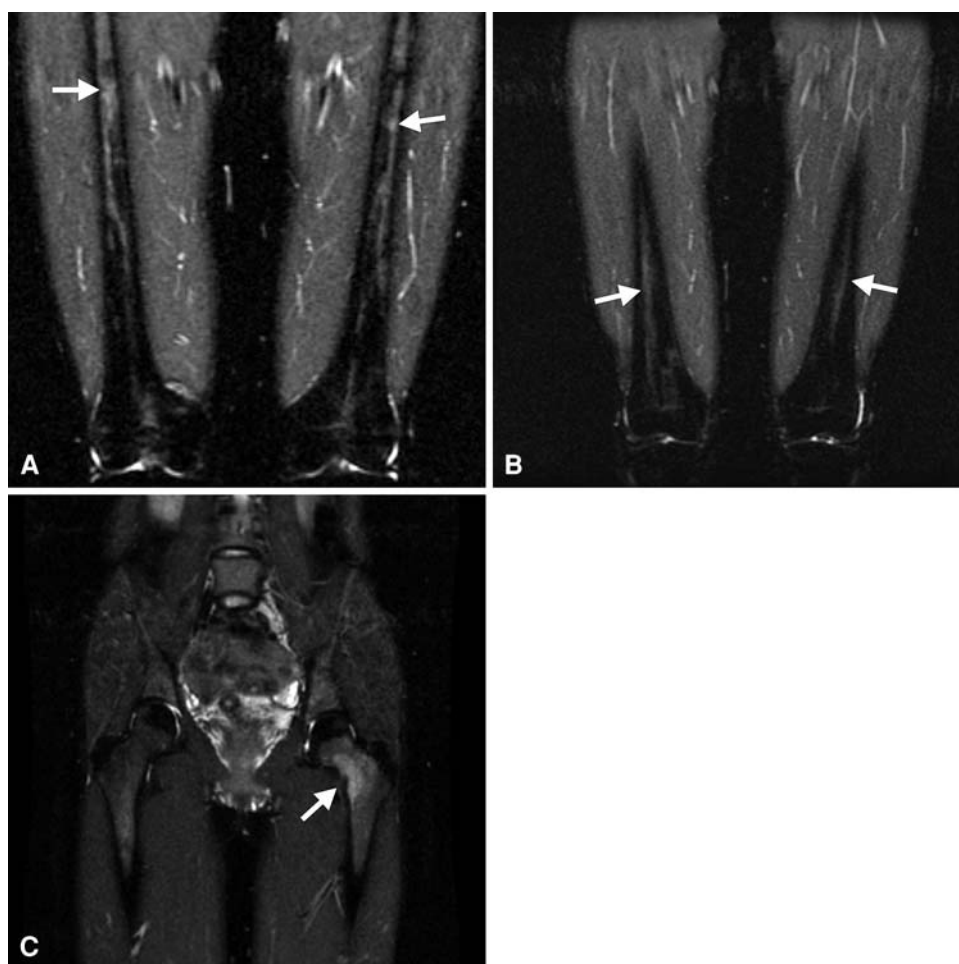


Fig. 2A–C A 19-year-old female trainee had slight, bilateral hip pain and low back pain of varying intensity from the first month onward during the course. Pain intensity in the left hip was somewhat increased during the second month of the 3-month course but remained low. Coronal images reveal endosteal marrow edema in the middle and distal femoral shafts on the (A) first and (B) third MR images (arrows). (C) A tiny fracture line with surrounding edema is seen in the left femoral neck on the second MR image (arrow).



loading, MRI with adequate followup has been recommended to diagnose a possible femoral neck injury [23].

In the current study, the most common anatomic location of bone stress injuries was the femoral shaft, in which $\frac{1}{2}$ of the injuries occurred. This is in accordance with the literature, which shows, when running constitutes the major

part of the physical training program such as in military training, bone stress injuries of the femoral and tibial shaft are common [6, 21]. Femoral shaft injuries were discovered during the first and third MRI examinations in all subjects, and they were either solitary or combined with another injury in a different location. In a report with

Fig. 3A–B A 19-year-old female trainee had slight right knee pain from the first month onward of the 3-month course. **(A)** A low signal fracture line with surrounding high signal intensity marrow edema and soft tissue edema in the tibial condyle is seen on the first MR image (arrow). **(B)** A Grade IV fracture line can be seen in the same female trainee on the second MR image (arrow).

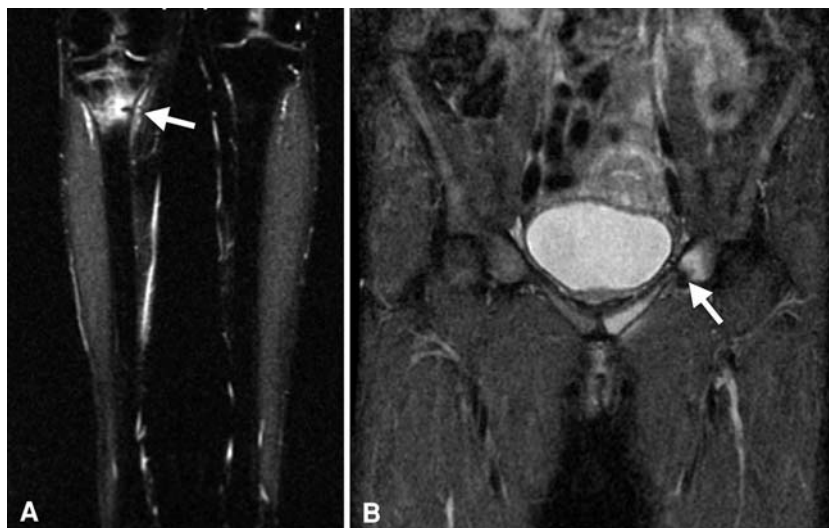


Table 2. Positive MRI findings and their correlation to positive symptoms and grade

Bone	Number of positive MRI findings/number of symptomatic cases (MRI grade)		
	First MRI	Second MRI	Third MRI
Sacrum			1/1 (IV)
Ramus	2/2* (V, III)		
Femur			
Collum		1/1 (IV)	1/1 (IV)
Diaphyses	20/7 (I)	14/1 (I)	18/1 (I)
Condyle			
Tibia			
Condyle	1/1 (IV)	1/0 (IV)	1/0 (IV)
Diaphyses	6/5 (II, V)	6/1 (I)	17/2 (I)
Fibula	1/1 (I)		
Total (90/24 [27%])	30/16 (53%)	22/3 (14%)	38/5 (13%)

* Left upper ramus was Grade V and left lower ramus was Grade III; this trainee interrupted the course owing to other health reasons.

similar findings, low-grade femoral shaft injuries were found in association with high-grade injuries [17]. At the second MRI examination, the number of femoral shaft injuries was lower compared with the first and third examinations, probably because of the different amount of endosteal edema resulting from the preceding lower physical strain. All femoral shaft injuries presented as endosteal marrow edema (Grade I), and despite continued training, subsequent MRI findings did not show any worsening of the injuries. In the previous 5.8-year MRI-based study with focus on distribution of stress injuries of the femoral bone, 20% of injuries occurred in the proximal third of the femoral shaft, whereas the number of injuries in the middle and distal shaft amounted to only a small percentage [23]. In our study, nearly ½ of bone stress injuries occurred in the tibial shaft.

We found symptoms occurred in approximately ⅓ of the bone stress injuries compared with approximately 40% in a previous study among a group of elite male conscripts [16]. According to the literature, the general symptom of a bone stress injury typically begins after marching, running, or exercise, intensifying if the physical activity is continued and usually disappearing with rest [8]. When bone stress injuries become more severe, the pain can progress and become constant. Owing to the often insidious onset of symptoms, clinical diagnosis of these injuries may be difficult and nonspecific [27]. We observed similar findings because, regardless of the strong suspicion by the experienced orthopaedic surgeon, there were no specific findings in the clinical examination on which a bone stress injury diagnosis could have been based. Therefore, imaging studies are always needed to confirm or rule out diagnosis of an injury [3].

It is widely believed female gender is a general risk factor for bone stress injuries. It was shown MRI-diagnosed bone stress injuries of the pelvis and femoral neck are substantially more common among female recruits than among male conscripts [1, 17, 22]. In the current study, repeated MRI examinations of female military recruits undergoing heavy physical training revealed not only symptomatic high-grade bone stress injuries but also a great number of asymptomatic low-grade bone stress injuries. Regardless of the MRI findings, the women expressed only mild to moderate symptoms. Asymptomatic, low-grade injuries of the femoral and tibial shaft seem to remain constant in female trainees without progressing to higher grades even when heavy physical activity is continued, suggesting routine screening of asymptomatic trainees is not required. However, symptomatic subjects should undergo MRI, especially if they have groin and hip pain and when a femoral neck bone stress injury is suspected.

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References

- Ahovuo JA, Kiuru MJ, Visuri T. Fatigue stress fractures of the sacrum: diagnosis with MR imaging. *Eur Radiol.* 2004;14:500–505.
- Almeida SA, Williams KM, Shaffer RA, Brodine SK. Epidemiological patterns of musculoskeletal injuries and physical training. *Med Sci Sports Exerc.* 1999;31:1176–1182.
- Anderson MW, Greenspan A. Stress fractures. *Radiology.* 1996;199:1–12.
- Beck TJ, Ruff CB, Shaffer RA, Betsinger K, Trone DW, Brodine SK. Stress fracture in military recruits: gender differences in muscle and bone susceptibility factors. *Bone.* 2000;27:437–444.
- Bennell KL, Malcolm SA, Thomas SA, Reid SJ, Brukner PD, Ebeling PR, Wark JD. Risk factors for stress fractures in track and field athletes: a twelve-month prospective study. *Am J Sports Med.* 1996;24:810–818.
- Bennell KL, Malcolm SA, Thomas SA, Wark JD, Brukner PD. The incidence and distribution of stress fractures in competitive track and field athletes: a twelve-month prospective study. *Am J Sports Med.* 1996;24:211–217.
- Brudvig TJ, Gudger TD, Obermeyer L. Stress fractures in 295 trainees: a one-year study of incidence as related to age, sex, and race. *Mil Med.* 1983;148:666–667.
- Burr DB, Milgrom C. *Musculoskeletal Fatigue and Stress Fractures.* Boca Raton, FL: CRC Press; 2001.
- Daffner RH, Pavlov H. Stress fractures: current concepts. *AJR Am J Roentgenol.* 1992;159:245–252.
- Fredericson M, Bergman AG, Hoffman KL, Dillingham MS. Tibial stress reaction in runners: correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. *Am J Sports Med.* 1995;23:472–481.
- Giladi M, Milgrom C, Simkin A, Danon Y. Stress fractures. Identifiable risk factors. *Am J Sports Med.* 1991;19:647–652.
- Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN. Epidemiology of injuries associated with physical training among young men in the army. *Med Sci Sports Exerc.* 1993;25:197–203.
- Jones BH, Knapik JJ. Physical training and exercise-related injuries: surveillance, research and injury prevention in military populations. *Sports Med.* 1999;27:111–125.
- Kiuru MJ, Niva M, Reponen A, Pihlajamäki HK. Bone stress injuries in asymptomatic elite recruits: a clinical and magnetic resonance imaging study. *Am J Sports Med.* 2005;33:272–276.
- Kiuru MJ, Pihlajamäki HK, Ahovuo JA. Fatigue stress injuries of the pelvic bones and proximal femur: evaluation with MR imaging. *Eur Radiol.* 2003;13:605–611.
- Kiuru MJ, Pihlajamäki HK, Ahovuo JA. Bone stress injuries. *Acta Radiol.* 2004;45:317–326.
- Kiuru MJ, Pihlajamäki HK, Perkio JP, Ahovuo JA. Dynamic contrast-enhanced MR imaging in symptomatic bone stress of the pelvis and the lower extremity. *Acta Radiol.* 2001;42:277–285.
- Korpelainen R, Orava S, Karpakka J, Siira P, Hulkko A. Risk factors for recurrent stress fractures in athletes. *Am J Sports Med.* 2001;29:304–310.
- Li GP, Zhang SD, Chen G, Chen H, Wang AM. Radiographic and histologic analyses of stress fracture in rabbit tibias. *Am J Sports Med.* 1985;13:285–294.
- Lohman M, Kivisaari A, Vehmas T, Kallio P, Malmivaara A, Kivisaari L. MRI abnormalities of foot and ankle in asymptomatic, physically active individuals. *Skeletal Radiol.* 2001;30:61–66.
- Matheson GO, Clement DB, McKenzie DC, Taunton JE, Lloyd-Smith DR, MacIntyre JG. Stress fractures in athletes: a study of 320 cases. *Am J Sports Med.* 1987;15:46–58.
- Mattila VM, Niva M, Kiuru M, Pihlajamäki H. Risk factors for bone stress injuries: a follow-up study of 102,515 person-years. *Med Sci Sports Exerc.* 2007;39:1061–1066.
- Niva MH, Kiuru MJ, Haataja R, Pihlajamäki HK. Fatigue injuries of the femur. *J Bone Joint Surg Br.* 2005;87:1385–1390.
- Pihlajamäki HK, Ruohola JP, Kiuru MJ, Visuri TI. Displaced femoral neck fatigue fractures in military recruits. *J Bone Joint Surg Am.* 2006;88:1989–1997.
- Pihlajamäki HK, Ruohola JP, Weckstrom M, Kiuru MJ, Visuri TI. Long-term outcome of undisplaced fatigue fractures of the femoral neck in young male adults. *J Bone Joint Surg Br.* 2006;88:1574–1579.
- Salminen ST, Pihlajamäki HK, Visuri TI, Bostman OM. Displaced fatigue fractures of the femoral shaft. *Clin Orthop Relat Res.* 2003;409:250–259.
- Shin AY, Morin WD, Gorman JD, Jones SB, Lapinsky AS. The superiority of magnetic resonance imaging in differentiating the cause of hip pain in endurance athletes. *Am J Sports Med.* 1996;24:168–176.
- Sormaala MJ, Niva MH, Kiuru MJ, Mattila VM, Pihlajamäki HK. Bone stress injuries of the talus in military recruits. *Bone.* 2006;39:199–204.
- Tuan K, Wu S, Sennett B. Stress fractures in athletes: risk factors, diagnosis, and management. *Orthopedics.* 2004;27:583–591; quiz 592–593.